

# **Principles of Physics**

**Sixth Edition, with SI Units**

**M. Nelkon M.Sc., F.Inst.P., A.K.C.**

M. Nelkon M.Sc., F.Inst.P., A.K.C.  
Formerly Head of the Science Department, William Ellis School, London

# **Principles of Physics**

Sixth Edition, with SI Units

Hart-Davis Educational

Granada Publishing Limited  
Hart-Davis Educational Limited  
First published in Great Britain 1951 by Christophers  
Reprinted 1953, 1954, 1956  
Second edition 1956 published by Chatto & Windus Educational Limited  
Reprinted 1957 (twice), 1958, 1959, 1960  
Third edition 1961, 1962  
Fourth edition 1964, 1965, 1967, 1968 (twice), 1970  
Completely New Edition, SI Units 1973 (twice), 1974 (twice)  
Sixth edition 1975 published by Hart-Davis Educational Limited  
Frogmore, St Albans, Hertfordshire  
Reprinted 1975 (twice), 1976, 1977

Copyright © M. Nelkon 1973, 1975, 1977

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the publishers.

ISBN 0 7010 0629 3 (cased)  
0 7010 0633 1 (limp)

Filmset in Photon Times 11 pt. by  
Richard Clay (The Chaucer Press), Ltd, Bungay, Suffolk  
and printed in Great Britain by  
Fletcher & Son Ltd, Norwich

## **Note on 1977 Reprint**

In this reprint, the text concerned has been adjusted to show how the specific heat capacity of a metal can be found by transfer of mechanical energy to heat, and more recent examination questions have been added to the exercises.

I am particularly indebted to Chief Olu Ibukun, UNESCO Regional Office of Science and Technology for Africa, for the new photograph showing a scientist at work at the Solar Energy Laboratory, University of Dakar, Senegal.

## **Preface to Sixth Edition**

In this edition, I have added: (a) a concise 'Introduction to Astronomy' chapter 35, covering the main points required in the Ordinary level Nuffield syllabus; (b) another Multiple Choice question paper for further examination practice; (c) clarification of some points in the text and recent examination questions; (d) additional photographs at the beginning of chapters.

The author is indebted to many correspondents at home and abroad for their constructive comments, especially F. Anstis, Reed's School, Surrey, J. Lister, Wheelwright Grammar School for Girls, A. Loizou, The English School, Cyprus, and W. G. Sale, Nairobi, Kenya. He is particularly grateful to Dr R. A. McCurrie, University of Bradford, for his advice on domain theory in magnetism.

## Preface to 1973 Edition

*Principles of Physics* was first published in 1951 and during the succeeding years it has been regularly brought up to date as new topics have been included in the GCE O level syllabuses. However, there has been so much change in these years that the time has now come for a complete replanning of the book in SI Units.

In this new edition, the text is based on the revised Ordinary level syllabus of the Examination Boards and the Nuffield Ordinary level examinations.

The book has been completely redesigned and reset with **new diagrams and photographs**.

Among the changes for this new edition, mention may be made of the following:

- (1) **SI units** have now been used. Where they are more convenient for calculations, allowed sub-multiples of mass and length, the gramme and centimetre, have also been used;
- (2) in *Dynamics*, vectors and scalars, linear momentum and circular motion have been discussed and modern apparatus introduced;
- (3) in *Heat*, the joule is used as the heat unit, electrical heating has been utilized, and conversions to heat energy discussed;
- (4) an introduction to the molecular view of solids, liquids and gases, and to the properties of matter, has been given in *Molecules and Matter*;
- (5) in *Waves*, the differences between matter waves and electromagnetic waves have been discussed, their common properties described, and an introduction to interference and diffraction has been given;
- (6) in *Electricity*, prominence has been given to electrons and ions as charge carriers in metals and electrolytes, to the link between potential difference and energy, and to the concept of magnetic fields in electromagnetism;
- (7) the section on *Electronics* contains an account of hot and cold cathodes, the diode valve, the fine beam tube and its uses, and to semiconductors, junction diode and transistor amplifier;
- (8) the final chapter on *Radioactivity* includes an introduction to atomic structure and nuclear energy.

Many worked examples have been given in the text in illustration of the subject matter and there are numerous exercises to assist comprehension. It is hoped that the book will provide a useful modern introduction to the principles of the subject.

I am very much indebted to the following for their assistance in compiling the work: M. V. Detheridge, William Ellis School, London and S. S. Alexander, Woodhouse Grammar School, London; L. J. Beckett, William Ellis School, London; R. P. T. Hills, St. John's College, Cambridge; and T. E. Walton, William Ellis School, London. I am also indebted for valuable advice in earlier considerations to F. C. Brown, head of the physical sciences department, Institute of Education, London University.

## Acknowledgements

THE author and publishers are very grateful for permission to reprint questions set in past examinations by the following Examining Boards: London University School Examinations Council (*L.*); Joint Matriculation Board (*N.*); Oxford and Cambridge Joint Board (*O.* and *C.*) Cambridge Local Examinations Syndicate (*C.*); Oxford Local Examinations Syndicate (*O.*).

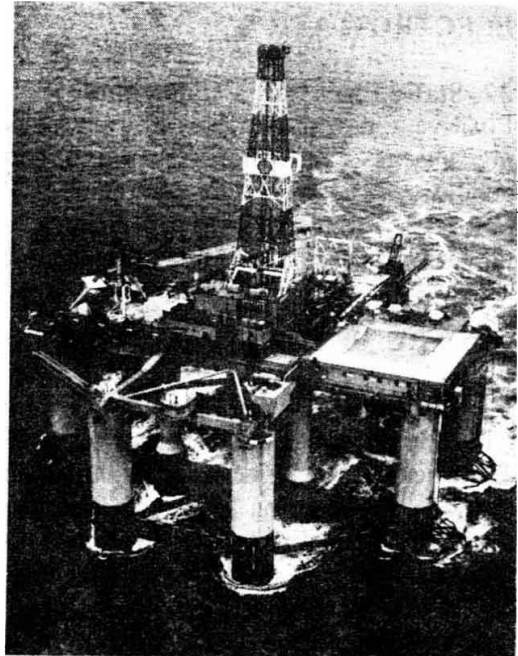
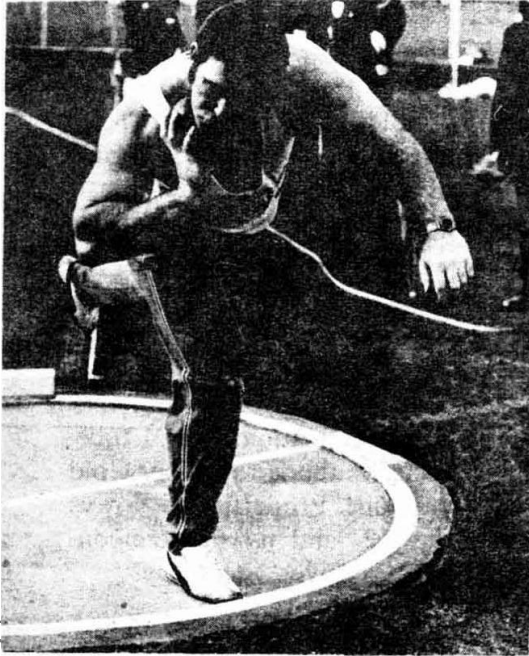
The author is indebted to the examining boards listed for their kind permission to translate numerical values in past questions into SI units; the translation is the sole responsibility of the author.

The author and publishers are also indebted to the following firms and organizations, whose names are given alphabetically for convenience, for supplying photographs and information in connection with the following plates:

Almasy, p. 172; Associated Press Ltd, 3B, p. 632; Australian Information Service, p. 350; Barf and Stroud Ltd, 18B; British Aircraft Corporation, p. 257; British Oxygen Co., pp. 181, 222; Central Office of Information, 20c; Central Electricity Generating Board, p. 574; Central Electricity Research Laboratories, p. 524; Ceramic Research, A.E.R.E., p. 146; Chloride Storage Co., 25A, B; *Daily Mail*, p. 308; De Beers Ltd, p. 287; Doulton Insulators Ltd, p. 404; Dunlop Ltd, 8E, F; Electrical Musical Industries Ltd, p. 387; Elliot-Automation, 30A, 33C; Ferranti Ltd, 26A, p. 575; Fibreglass Ltd, 14A; Flight International, p. 335; Fox Photos Ltd, p. 70; A. T. Freeman, p. 427;

## ACKNOWLEDGEMENTS

Frigidaire, 13A; G.E.C. Ltd, Witton Kramer Div., p. 476; Goodman's Loudspeakers Ltd, 30C, D; Goodyear Tyre and Rubber Co. (Great Britain) Ltd, pp. 123, 194; Griffin and George Ltd, 22A, B, C, F, H; Hale Observatories, p. 633; High Commissioner for New Zealand, p. xiv; Hird-Brown Ltd, p. 444; Hovercraft Development Ltd, 8G; Hydraulic Research Station, p. 351; John Laing and Son Ltd, p. 87; Keystone Press Agency, p. 545; Leybold-Heraeus GMB & Co. (Photo: Dr H. W. Franke), 33B; Dr R. A. McCurrie, 28.13; Mallory Batteries Ltd, p. 405; Ministry of Defence, p. 39; Morris Laboratory Instruments, 8B; Mullard Ltd, 33A, D, E; 3M Company, 28A; N.A.S.A., pp. 206, 239; National Physical Laboratory, 3A, 8H, I, p. 173; Negretti and Zambra Ltd, 6A; W. B. Nicolson (Glasgow) Ltd, 2A, 34D; Omega Watch Co., p. 13; P. and O. Orient Lines, 20A, p. 265; Panax Equipment Ltd, 34A; Paul Popper Ltd, p. 12; Plessey Ltd, 29A, B, C; Polaroid (U.K.) Ltd, p. 320; Post Office, pp. 493, 544; Rainbow Radio Ltd, 22G; Redferns, p. 386; Royal Festival Hall, 23A; Royal Free Hospital (Photo: Walter Nurnberg), 34C; Science Museum (P. M. S. Blackett), 34E; Scientific Teaching Apparatus Ltd (Leybold), 8A; G. Severn, Esq., 2B, C; Shell International Petroleum Co. Ltd, 22D, E, p. xiv; *Skate Monthly Magazine*, p. 102; Smiths Industries Ltd, 14B, 21A; Sport and General Press Agency, p. xiv; *Sunday Telegraph*, p. 256; I. D. B. Taylor, Esq., 8C, D; Thorn Lighting Ltd, p. 1; Tracked Hovercraft Ltd, p. 508; Triplex Glass Co. Ltd, p. 146; U.K. Atomic Energy Authority, 18A, 32A, 34B, G, H; Unilever Ltd, 8J; U.S. Information Services, 3A, 33F, pp. 175, 274, 603; Vauxhall Ltd, 12A, B, 34F; White Electrical Instrument Co., 26B, 30B; Prof. M. Wilkins, p. 147; Wingard Ltd, p. 27; Yardley Ltd, p. xiv.



Physics in action. *Top:* A Formula 1 racing car capable of speeds up to nearly 300 km/h. *Centre left:* A world class shot-putter can propel the 7.26 kg shot more than 21 m. *Centre right:* One of the latest drilling platforms of the type used to prospect for oil beneath the sea. *Bottom:* An active volcano: Mt Ngaruahoe, New Zealand, during eruption.



# Contents

	<i>page</i>
<b>Preface</b>	v
<b>Acknowledgements</b>	vii
<b>1 Introduction</b>	1
Theory and Experiment. Forms of Energy. Units. Measurements. Graphs.	
<b>MECHANICS AND FLUIDS</b>	
<b>2 Dynamics</b>	13
Speed. Velocity. Acceleration. Retardation. Equations of linear motion. Measurement of $g$ by centisecond clock. Pendulum method. Displacement–time and Velocity–time graphs. Scalars and vectors. Components of $g$ . Summary.	
<b>3 Force · Momentum · Energy · Power</b>	39
Force and acceleration. Forces of gravity and friction. Inertial mass. Investigations of $F = ma$ . Units. Gravitational attraction and weight. Friction and motion. Terminal velocity. Circular motion and acceleration. Force and Momentum. Conservation of linear momentum. Work. Energy. Potential and kinetic energy. Conservation of energy. Power. Summary.	

## CONTENTS

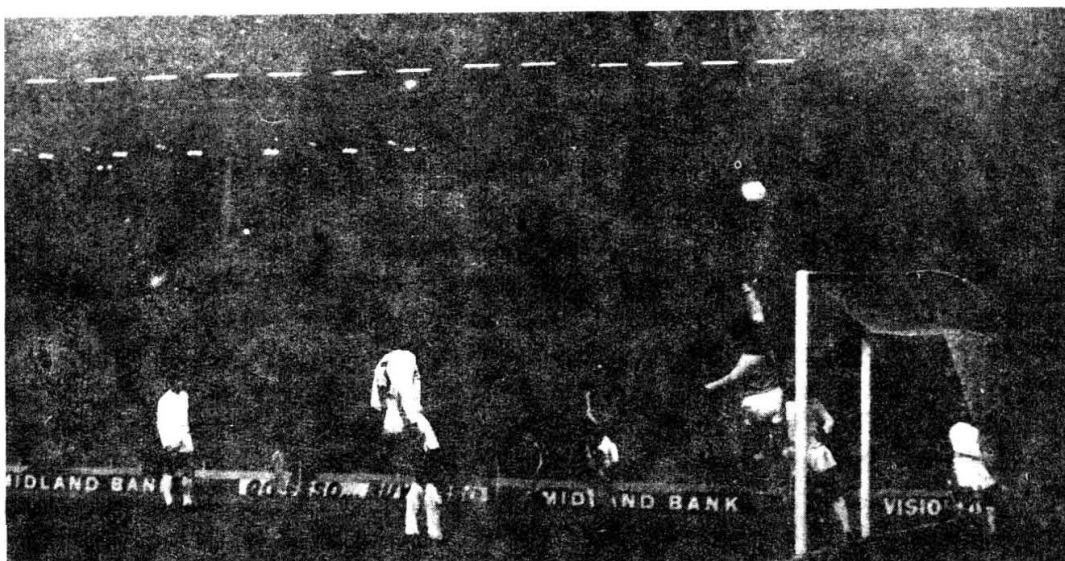
<b>4 Forces and Moments</b>	70
Moments. Applications. Equilibrium and moments. Equilibrium of parallel forces. Classes of levers. Centre of gravity. Stable, unstable, neutral equilibrium. Summary.	
<b>5 Machines · Resultant of Forces</b>	87
Mechanical advantage, velocity ratio, efficiency. Levers. Pulleys. Inclined plane. Screw. Screw-jack. Parallelogram of forces. Resultant. Equilibrant. Components. Summary.	
<b>6 Pressure in Fluids</b>	102
Pressure—meaning and units. Variation with depth and density. Some laws of pressure. Hydraulic press. Atmospheric pressure. Simple and Fortin barometer. Units and magnitude of air pressure. Aneroid barometer. Siphon. Gas pressure. Boyle's law. Summary.	
<b>7 Density · Forces Due to Fluids</b>	123
Density. Upthrust. Investigations. Archimedes' principle. Measurement of density and relative density. Floating objects. Principle of flotation. Balloons, ships, floating docks, submarine, Plimsoll line. Hydrometers. Summary.	
<b>MOLECULES AND MATTER</b>	
<b>8 Molecules and Matter</b>	147
Solid, liquid gaseous states. Size of molecules. Oil film. Diffusion of molecules. Osmosis. Brownian motion. Elasticity, Hooke's law. Friction—static and kinetic, advantages, disadvantages. Surface tension. Capillarity. Summary.	
<b>HEAT</b>	
<b>9 Temperature and Thermometers</b>	173
Thermometers. Fixed points. Making thermometer and calibration. Celsius and Kelvin scales. Alcohol, maximum and minimum, gas and thermoelectric thermometers. Summary.	
<b>10 Thermal Expansion of Solids and Liquids</b>	181
Solids. Effects of expansion. Bimetal applications, thermostat. Linear expansivity. Determination. Formulae. Liquid and cubic expansivity. Hooke's experiment. Volume and density variation of water. Summary.	
<b>11 Thermal Expansion of Gases</b>	194
Gas laws. Volume expansion at constant pressure—experiment and coefficient. Absolute temperature. Pressure change at constant volume—experiment and coefficient. Constant-volume gas thermometer. General gas law, $pV/T = \text{constant}$ . Conversion to s.t.p. Kinetic theory explanation of gas laws. Summary.	

<b>12 Heat Capacity · Heat Energy</b>	206
Joule as unit of heat. Electrical heating. Heat capacity, specific heat capacity. $Q = mct$ . Calorimeters. Measurements. Molecular explanation of heat capacity. Transformation of energy and work into heat. Internal-combustion engine. Sun and energy transformations. Summary.	
<b>13 Change of State · Latent Heats · Vapours</b>	222
Latent heat of fusion. Molecular explanation. Melting point. Freezing and melting of water and ice. Regelation. Latent heat of vaporization. Evaporation. Factors affecting evaporation. Molecular explanation. Refrigerator. Saturation vapour pressure. Molecular explanation. Boiling and s.v.p. Effect of pressure changes. Pressure cooker. Summary.	
<b>14 Transmission of Heat</b>	239
Conduction. Molecular explanation. Metals and non-conductors. Conductivity of water. Ignition temperature. Convection currents in liquids. Hot-water system. Convection in gases. Land and sea breezes. Radiation. Emission and absorption. Infra-red radiation. Summary.	
<b>OPTICS</b>	
<b>15 Rectilinear Propagation of Light</b>	257
Luminous and non-luminous objects. Rays and beams of light. Shadows. Ellipses. Pin-hole camera. Summary.	
<b>16 Reflection at Plane Mirrors</b>	265
Reflection of rays. Diffuse reflection. Laws of reflection. Periscopes. Formation of images—virtual and real images. Location of image. Lateral inversion. Inclined mirrors. Summary.	
<b>17 Curved Spherical Mirrors</b>	274
Reflection of rays. Parabolic mirror. Centre and radius of curvature. Focal length. Images in curved mirrors. Real and virtual images. Ray drawings. Magnification. Convex mirror. Formulae. Summary.	
<b>18 Refraction at Plane Surfaces</b>	287
Refraction in solids and liquids. Apparent depth. Partial-immersion in water. Glass prism refraction. Laws. Refractive index. Total internal reflection. Critical angle. Total reflecting prisms. Mirages. Summary.	
<b>19 Refraction Through Lenses</b>	308
Converging (convex) and diverging (concave) lenses. Action on rays. Focal length of converging lens. Images in lenses. Magnifying lens. Magnification. Formulae. Summary.	
<b>20 Applications of Lenses</b>	320
The eye. Binocular vision. Accommodation. Normal vision—near and far point. Defects of vision. Lens camera. Projection lantern. Simple and compound microscope. Astronomical telescope. Prism binoculars. Galilean telescope. Summary.	

## CONTENTS

<b>21 Colours of Light · The Spectrum</b>	335
Colours in white light. Dispersion and recombination. Newton's colour disc. Formation of pure spectrum. Colours of objects. Additive and subtractive colour mixing. Ultra-violet and infra-red rays. Summary.	
<b>WAVES</b>	
<b>22 Wave Propagation · Wave Effects</b>	351
Ripple tank. Water waves. Wavelength, frequency, velocity. Transverse and longitudinal waves. Sound, light, electromagnetic waves. Resonance. Reflection, refraction. Interference. Young's experiment. Stationary waves. Diffraction, diffraction grating. Summary.	
<b>SOUND</b>	
<b>23 Basic Principles of Sound · Strings and Pipes</b>	387
Sound wave—rarefactions, compressions. Pitch, intensity, timbre. Echoes. Echo-sounding. Vibrations in strings. Sonometer. Closed pipe. Resonance tube experiment, velocity of sound. Summary.	
<b>CURRENT ELECTRICITY</b>	
<b>24 Current, Potential Difference, Resistance</b>	405
Electric current. Charge carriers. Conductors, Insulators. Semiconductors. Ammeter. Potential difference. Voltmeter. Ohm's law. Fundamental formulae. Measurement of resistance. Effect of temperature. Resistances in series and parallel. Resistivity. Summary.	
<b>25 Batteries · E.m.f. and Circuits</b>	427
Voltaic cell. Simple cell. Leclanché dry cells. Accumulator, discharging and charging. E.m.f. and terminal p.d. Internal resistance. Series and parallel cells. Potentiometer. Circuit calculations. Summary.	
<b>26 Electrical Energy and Power</b>	444
Electrical energy. <i>IVt</i> . Machines. Power. E.m.f. and energy. Electrical lamps. Kilowatt-hour. Heating effect—Joule's laws. Hot-wire ammeter. High-voltage transmission. Domestic installations. Fuses. Summary.	
<b>27 Chemical Effect of Current</b>	462
Electrolytes. Electrolysis. Hoffmann voltameter. Applications. Faraday's first law. Electrochemical equivalent. Ammeter calibration. Faraday's second law. Faraday constant. Ionic explanations. Summary.	
<b>28 Magnetism</b>	476
Fundamental laws. Methods of making magnets. Demagnetization. Materials. Ferrites. Magnetic fields. Neutral points. Induction. Shielding. Domain theory. Summary.	
<b>29 Magnetic Effect of Current</b>	493
Oersted's experiment. Forces due to magnetic fields. Straight wire, circular coil, solenoid. Electromagnets. Magnetic relay. Telecommunications. Moving-iron ammeter. Summary.	

<b>30 The Motor Force</b>	508
Interaction with magnetic fields. Rules for direction. Faraday motor. Rectangular coil and moving-coil instrument. Extension of range. Conversion to voltmeter. Motor and commutator. Loudspeaker. Forces between currents. Current balance. Summary.	
<b>31 Electromagnetic Induction</b>	524
Induced e.m.f., current. Bicycle dynamo. Primary, secondary coils. Ignition coil. Faraday. Lenz. Speedometer. Fleming's rule. Simple dynamo; a.c. and d.c. Transformers. High-voltage transmission. Summary.	
<b>ELECTROSTATICS</b>	
<b>32 Static Electricity · Capacitors</b>	545
Positive and negative charges. Fundamental laws. Gold-leaf electroscope. Testing charges. Induction. Action at points. Electrophorus. Van de Graaff generator. Electric fields. Screening. Positive and negative potential. Earth potential. Effects of static electricity. Capacitance. Factors affecting capacitance. Units. Practical capacitors. Summary.	
<b>ATOMIC PHYSICS</b>	
<b>33 Electrons · Electronics</b>	575
Thermionic emission. Hot cathodes. Diode valve. Rectification. Perrin tube. Fine beam tube. Electric and magnetic field effects. Cathode-ray tube. Cold cathode. Conduction in gases. Cathode rays. X-ray tube. Properties of X-rays and nature. Semiconductors. Electrons and holes. P- and n-type semiconductors. Junction diode. Transistor amplifier. Simple receiver. Summary.	
<b>34 Radioactivity · Atomic Structure · Nuclear Energy</b>	603
Geiger-Muller tube and scaler. Alpha, beta, particles, gamma-rays. Ionization and penetrating powers. Diffusion cloud chamber. Random decay. Half-life period. Geiger and Marsden experiment. Protons and neutrons. Atomic structure. Transmutations. Isotopes. Einstein mass-energy relation. Nuclear fission. Nuclear fusion. Conclusion.	
<b>ASTRONOMY</b>	
<b>35 Introduction to Astronomy</b>	631
Observed motion of sun and stars. The ecliptic. The moon and phases. Greek astronomy. Copernican theory. Newton and gravitation. Newton's universal law. Earth satellites. Gravitational acceleration on moon. Summary.	
<b>Multiple-choice Questions</b>	651
<b>Answers to Exercises</b>	667
<b>Index</b>	673
<b>SI Units</b>	686



Soccer at Wembley Stadium, London. The photograph shows changes of (i) chemical energy to mechanical energy (in the form of kinetic and gravitational potential energy), (ii) electrical energy to light energy, (iii) potential to kinetic energy and vice versa.

1.

## Introduction

### Theory and Experiment · Forms of Energy · Units · Measurements · Graphs

PHYSICS is a science concerned with the behaviour of matter. Some of its branches are electricity, optics, heat, sound, properties of matter and atomic theory.

Scientists of many different nationalities, such as British, American, Russian, French, Italian, Japanese and Chinese, are today engaged in researches in physics. As a result, many useful inventions and machines have been produced. Radar control at London and other large airports; computers in banks; colour television transmission by British and other national radio corporations; high-power microscopes for use in laboratories; and anti-skid tyres for cars, have all developed from researches in physics.

#### THEORY AND EXPERIMENT

In ancient times people believed something simply because a famous person said it. A good example occurred in the case of falling objects. A famous Greek philosopher called Aristotle said that heavy objects always fell to the ground faster than light objects. This was believed for nearly 2000 years.

An experiment showed that this statement was incorrect. A heavy and a light object were dropped together from the top of a tall building. (Legend

says that the building was the Leaning Tower of Pisa in Italy, which still exists.) It was observed that, contrary to what Aristotle thought, the heavy and the light object *both* reached the ground at the same time. Aristotle's theory was therefore wrong.

Today, scientists will not accept a theory unless there is experimental evidence to support it. If an experiment gives results which are contrary to the theory, the theory is abandoned or modified. Sometimes the result of an experiment suggests a theory. About 1910, for example, Lord Rutherford examined the results of an experiment by two of his research students at Cambridge. They were firing tiny particles at atoms. Some of the particles bounced off at large angles on making collisions. Some even bounced back. He came to the conclusion that the atom contained a very tiny concentrated mass in the middle which repelled the particles violently. He called it the *nucleus* of the atom. And this led years later to the discovery of nuclear energy and then to the development of the large nuclear power stations throughout Britain today.

#### FORMS OF ENERGY

'Work' and 'Energy' are two ideas which are widely used in all branches of physics.

A boy pulling a sledge or a girl pushing a pram are said to do *work*. Any object which produces movement is said to do work. Thus on climbing the stairs, we do work in moving our bodies upward. If an object has the capacity for doing work, it is said to have *energy*. The spring of a watch when wound up has energy because it moves gear wheels as it slowly unwinds. A cricket ball thrown at the wicket has energy because it can knock down the stumps.

The wound spring and the fast-moving cricket ball are examples of objects having *mechanical energy*. Over the past centuries, scientists gradually realized that there are many different forms of energy. An electric motor uses *electrical energy* to drive an electric train. *Light energy*, falling on a light meter used in photography, causes a pointer to move across a scale. *Sound energy* causes a microphone diaphragm or thin plate to vibrate. *Chemical energy* is the source of energy in our food which makes us grow and also provides us with muscular energy to move objects. *Nuclear energy*, the energy in the nucleus of atoms, produces heat energy, which in turn is used to generate electrical power in nuclear power stations.

#### ENERGY CONVERSIONS · PRINCIPLE OF CONSERVATION OF ENERGY

By means of suitable machines or apparatus, energy can be changed from one form to another. This is illustrated in Fig. 1.1. Thus a steam engine converts heat energy to mechanical energy. Mechanical energy is converted to heat energy when a match is struck. A light meter or photoelectric cell converts light energy to electrical energy. An electric lamp converts electrical energy to light energy. A solar cell converts the heat of the sun to electrical energy to power space ships. An electric fire converts electrical energy to heat energy. A microphone converts sound energy to electrical energy. A tele-

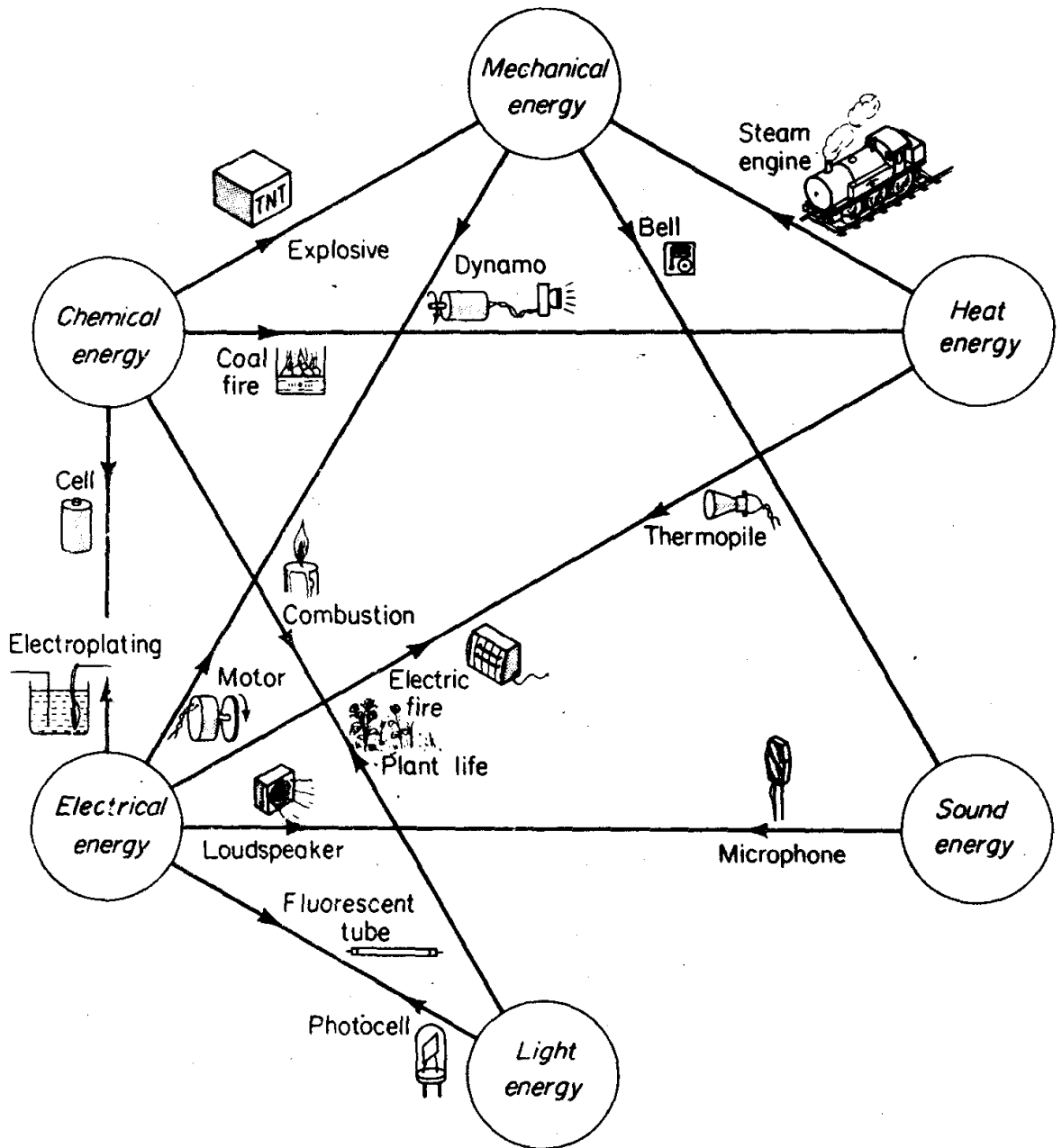


Fig. 1.1 Energy and transformations

phone earpiece converts electrical energy to sound energy. A battery converts chemical to electrical energy; a reverse change occurs in electroplating. The energy from the sun produces chemical changes which make plants and trees grow, and the energy is stored underground in coal centuries later, after the wood is absorbed by the soil and sinks.

An electric plant at a power station illustrates how energy can be changed from one form to another until a desired form of energy is produced. Coal is first burned, so that heat energy is produced from chemical energy. By means of a steam engine or turbine, the heat energy is converted into mechanical energy,



which turns the coils of an electric generator. Electrical energy is then produced. Electric lamps and heaters in homes and buildings now convert electrical energy to light and heat energy. Finally, the light energy collected by the eye falls on nerves in the retina, which stimulates the sensation of vision.

The heat energy received by the steam turbine is not all converted into mechanical energy. Some of the energy is wasted in overcoming the frictional forces in the wheels of the turbine. Sound energy is also produced by the spinning wheels owing to air disturbance. However, if the whole generating plant receives 100 units of energy, initially in the form of heat from the coal used, the total energy produced, calculated by adding together all the different forms of energy, will still be 100 units.

This leads to a generalization known as the *Principle of the Conservation of Energy*. It was arrived at after many years of experience, and it is recognized today as one of the most important principles in science. It states that, *in a given or closed system, the total amount of energy is always constant, although energy may be changed from one form to another.*

## Units · Measurements

### SYSTÈME INTERNATIONAL (SI) UNITS

A new system of units, known as the *Système International (SI) units*, has been adopted for all branches of physics. It is based on the metre as the unit of length, the kilogramme as the unit of mass, the second as the unit of time, the ampere as the unit of electric current and degrees kelvin as units of temperature. The unit of force in this system is the newton and the unit of energy is the joule (pp. 44, 55).

The *metre (m)* was for many years the distance between two lines on a particular platinum-iridium rod at 0°C which is kept near Paris. It is now defined as the length of a certain number of wavelengths in a vacuum of a particular orange radiation of the krypton-86 atom. Unlike the distance between the marks on the rod, the wavelengths are due to atomic vibrations and remain constant. Thus

$$1 \text{ m} = 1\,650\,763.73 \text{ wavelengths of the above radiation.}$$

The *kilogramme (kg)* is the mass of a particular solid cylinder made of platinum-iridium alloy kept in Paris, known as the International Prototype Kilogram.

The *mean solar day* is the average period between successive transits of the sun across the meridian, taken over twelve months, at any part of the earth's surface.

In practice, the following smaller units may also be used:

The *millimetre (mm)*, which is  $\frac{1}{1000}$  part of a metre.

The *centimetre (cm)*, which is  $\frac{1}{100}$  part of a metre.

The *gramme (g)*, which is  $\frac{1}{1000}$  part of a kilogramme.